





Synthesis Report on Observations, Projections and Impact Assessments of Climate Change, 2018

# “Climate Change in Japan and Its Impacts“

Ministry of the Environment
Ministry of Education, Culture, Sports, Science and Technology
Ministry of Agriculture, Forestry and Fisheries
Ministry of Land, Infrastructure, Transport and Tourism
Japan Meteorological Agency

# Observation Data and Future Projections of Climate Change (Global)

## Global Temperature will continue to rise in the future (Present/Projection)

Global annual mean surface temperature has increased at a rate of 0.72°C/100 years since the second half of the 19th century.
Global annual mean surface temperature for the end of the 21st century (2081-2100), compared to that for the end of the 20th century (1986-2005), is projected to rise by 0.3 to 1.7°C under the RCP2.6 scenario and 2.6 to 4.8°C under the RCP8.5 scenario.

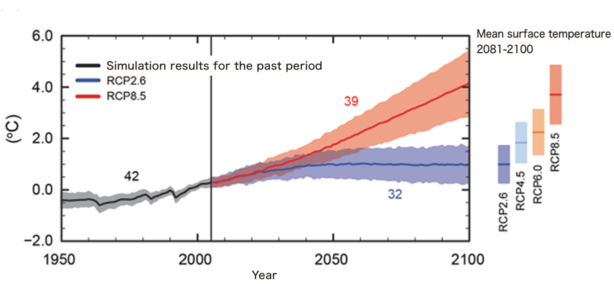


Figure 1. Projected changes in global annual mean surface temperature

Based on multi-climate-model simulations under the RCP2.6 scenario (purple) and the RCP8.5 scenario (red). The shading shows a measure of uncertainty. Source: Reference 1.

## Global ocean temperature is increasing (Present/Projection)

Ocean warming dominates the increase in energy stored in the climate system, accounting for more than 90% of the energy accumulated between 1971 and 2010.
Global annual mean sea surface temperature has increased at a rate of 0.53°C/100 years between 1891 and 2016.
Global ocean temperature is projected to keep increasing during the 21st century. Ocean warming in the top one hundred meters for the end of the 21st century is projected to increase by 0.6°C under the RCP2.6 scenario and 2.0°C under the RCP8.5 scenario.

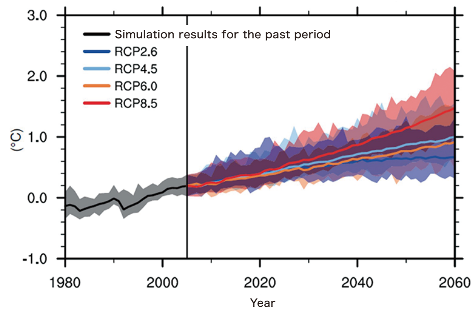


Figure 2. Projected changes in global annual mean sea surface temperature

Based on multi-climate-model simulations under the RCP2.6 scenario (blue), RCP4.5 scenario (light blue), RCP6.0 scenario (orange) and RCP8.5 scenario (red). The shading shows the 90% range of projected global annual mean sea surface temperature anomalies.
Source: Reference 2 (partially revised).

## Arctic sea-ice extent is decreasing (Present/Projection)

Arctic sea-ice extent has statistically significantly decreased since 1979. The decrease in the annual minimum sea-ice extent is particularly notable, and the decreasing rate per year is comparable with the area of Hokkaido Island.
It is very likely that the Arctic sea-ice cover will continue shrinking and thinning during the 21st century due to global warming.
The reduction of Arctic sea-ice extent in September for the end of the 21st century (2081-2100) is projected to decrease by 43% under the RCP2.6 scenario or 94% under the RCP8.5 scenario compared to the end of the 20th century (1986-2005). A nearly ice-free Arctic Ocean in September before mid-century is likely under the RCP8.5 scenario.

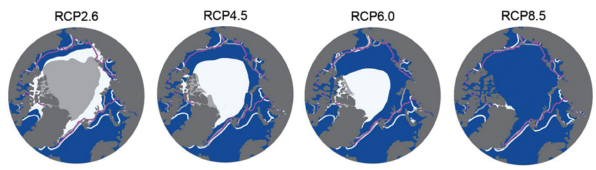


Figure 3. Projected changes in the Northern Hemisphere sea-ice extent in September

The white areas show the projected mean sea-ice extent for the end of the 21st century and the pink lines show the observed sea-ice extent at the end of the 20th century. Source: Reference 3.

## The maximum wind speed and precipitation of tropical cyclones are likely to increase【in certain regions】 (Projection)

The Fifth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC) projects that the global frequency of tropical cyclones will likely either decrease or remain essentially unchanged. The report also states that it is likely that both global mean maximum wind speed and amount of rainfall of tropical cyclones will increase, but there is low confidence in region-specific projections.
One of recent studies projects that very intense tropical cyclones (maximum wind speed of 59 m/s or higher) are likely to pass more frequently over the area from the seas to the south of Japan to Hawaii, as well as to the west of Mexico.

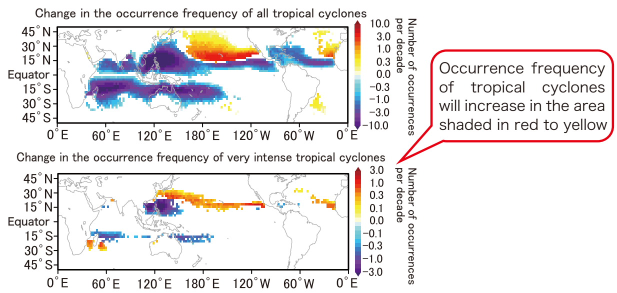


Figure 4. Examples of future projections for tropical cyclones

The unit on the right is the number of occurrences of tropical cyclones per decade. Future changes are shaded in color only for regions that are statistically significant. Source: Reference 4.

### Scenarios to project future climate change

Projection of climate change requires assumptions (scenarios) on how the concentrations of atmospheric greenhouse gases and the volume of atmospheric aerosols, which cause radiative forcing (effects that cause global warming), will change. The IPCC Fifth Assessment Report employs four scenarios (RCP2.6, RCP4.5, RCP6.0 and RCP8.5) depending on different radiative forcing levels possible in the future. The larger numbers following "RCP" indicate greater radiative forcing in 2100.
Due to a wide range of selected scenarios and imperfection of climate models for simulating the climate system, it must be noted that the projection of climate change contains uncertainty.

# Observation Data and Future Projections of Climate Change (Japan)

## The temperature over Japan is rising faster than the global average (Present/Projection)

Annual mean surface temperature over Japan, as with the global annual mean, has increased, with some fluctuations, at a rate of 1.19°C/100 years. Significantly high temperatures were recorded mostly in the 1990s and thereafter.
Projections with the four RCP scenarios indicate that annual mean temperature at the end of the 21st century will rise throughout Japan. Specifically, the RCP2.6 scenario projects an increase of 0.5 to 1.7°C, while the projected increase with the RCP8.5 scenario is 3.4 to 5.4°C, suggesting a greater increase at higher latitudes.

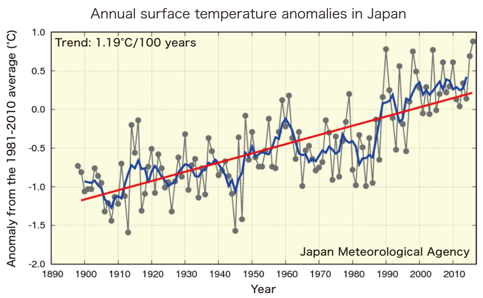


Figure 5. Annual surface temperature anomalies from 1898 to 2015 in Japan

Black: anomalies from the baseline (the 1981-2010 average); Blue: five-year running mean; Red: long-term linear trend. Source: Reference 5

## While heavy rainfall events are increasing, the number of days with precipitation is decreasing (Present/Projection)

The number of days with heavy rain (100mm/day) has increased. Additionally, the number of occurrences of events with extreme precipitation (50mm/hour or more according to AMeDAS (Automated Meteorological Data Acquisition System) data) is also increasing.*
On the other hand, the annual number of days with precipitation of 1.0 mm/day or more has decreased, and the overall number of days with precipitation has decreased.
The projection under the RCP8.5 scenario shows a statistically significant increase of events with extreme precipitation for the end of the 21st century for all areas and seasons. The number of days without precipitation for the end of the 21st century is projected to increase nationwide under the four RCP scenarios.

* Further accumulation of data is necessary to accurately identify long-term trends, since the data presently available with the AMeDAS pertain only to the observation period of roughly 40 years.

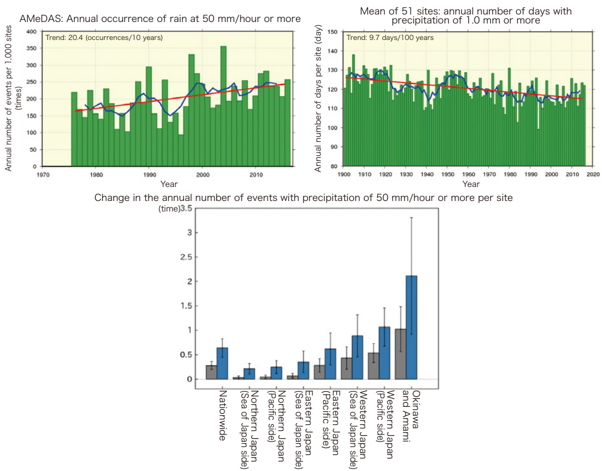


Figure 7. Observed change in the annual number of events with precipitation of 50 mm/hour or more (above left)
Observed change in the annual number of days with precipitation of 1.0 mm/day or more (above right)
Projected change in the annual number of events with precipitation of 50 mm/hour or more (below)

(Above left and above right) Bars: the number for each year; Blue line: five-year running mean; Red line: long-term linear trend
(Below) Bars: the number of occurrences per site (gray: present; blue: future); Thin black lines: the standard deviation of interannual variability. Source: References 5 and 6

## The number of days with a maximum temperature of 30°C/35°C or above is increasing (Present/Projection)

Annual number of days with a maximum temperatures of 30°C or above (called as "manatsu-bi" in Japanese) and 35°C or above ("mosho-bi" in Japanese) have increased for the period from 1931 to 2016 (the period when records are available). The annual number of "mosho-bi" increased at a rate of 0.2 days per 10 years.
Under the RCP8.5 scenario, the annual number of "mosho-bi" for the end of the 21st century is projected to increase, especially in the Okinawa and Amami region, where an increase of about 54 days is projected compared to the end of the 20th century.

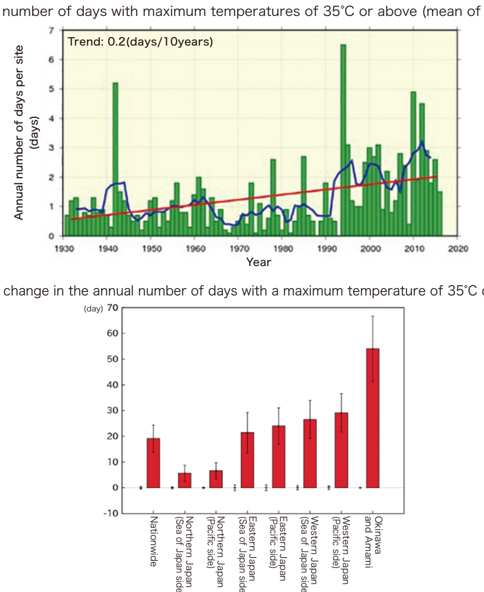


Figure 6 Observed change in the annual number of days with a maximum temperature of 35°C or above (above)
Projected change in the annual number of days with a maximum temperature of 35°C or above (below)

(Above) Bars: the number for each year; Blue line: five-year running mean; Red line: long-term linear trend
(Below) Bars: differences in days between the end of 20th and the end of 21st century; Thin black lines: the standard deviation of interannual variability Source: References 5 and 6

## While snow depth decreases in many areas, heavy snowfall may increase in inland areas (Present/Projection)

Annual maximum snow depth has decreased for the period between 1962 and 2016 on the Sea of Japan side of eastern Japan and on the Sea of Japan side of western Japan, at rates of 12.3% and 14.6% per decade, respectively.
The projection under the RCP8.5 scenario shows a large decrease in annual maximum snow depth and annual snowfall for the end of the 21st century, particularly on the Sea of Japan side of Honshu Island. On the other hand, the heavy snowfall occurring at a frequency of every 10 years is projected to occur more frequently in the inland areas of Honshu Island and Hokkaido Island.

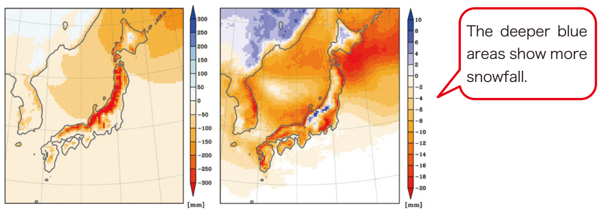


Figure 8. Example of projected change in total snowfall in the winter (November to March) (left)
Example of projected change in the heavy snowfall which occurs once every 10 years (daily snowfall) (right) Source: Reference 7

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# Impacts of Climate Change (Agriculture, Forests/Forestry and Fisheries)

Climate change causes various types of impacts on agriculture, forests/forestry and fisheries, depending on the areas and products. Due to higher temperatures such impacts include deterioration of product quality and the shifting of locations suitable for growing specific products.

## Impacts on rice yield and quality (Present/Projection)

Cases of white immature grain (high temperature or other damaging condition causes insufficient starch production in the grain, making it look milky white), cracked grain (high temperature causes cracks in the grain) and other degraded quality rice have already been reported throughout Japan. Some cases of reduction in yield have also been reported in specific areas or in extremely warm years.

Projections under the RCP4.5 scenario project a larger gap between areas where the yield of high-quality rice increases and where it decreases in the near future (2031-2050) and at the end of the 21st century (2081-2100).

It is also suggested that conditions where the temperature and $CO_2$ concentration are high would lower the yield of whole grain (undamaged perfect grain), an important index for rice quality.

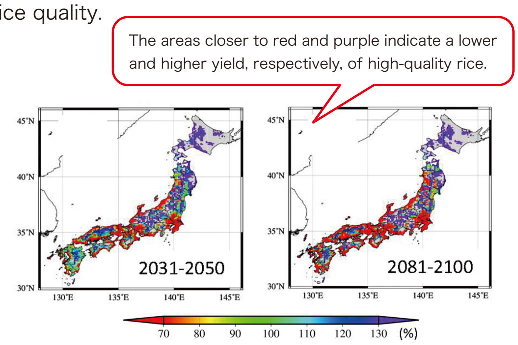


Figure 9. Change in the yield distribution of high-quality rice (mean over 20 years under the condition that no measures are taken; relative values when the mean between 1981 and 2000 is set as 100) Source: Reference 8

## Impact on Shiitake mushroom production (Present)

Temperature rise during the summer is suggested to impact Shiitake mushroom production due to the increased generation of pathogens and decreased generation of fruit-body (the mushroom part). However, further studies are needed to understand the impact more comprehensively.

Figure 11. Shiitake mushroom bed log infected with pathogens
Source: Reference 10 and 12

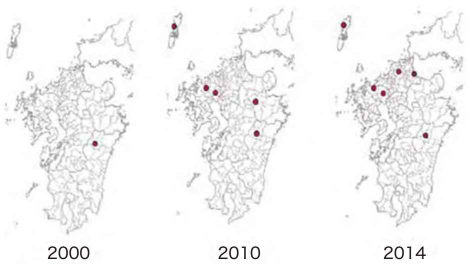


Figure 12. Increase in reported damage caused by Hypocrea spp bacteria in Kyushu
Source: Reference 10 and 12

## Impacts on the quality of fruit and locations suitable for fruit production (Present/Projection)

One impact of high temperature and minimal precipitation in the summer on fruit production is sunburn damage due to strong solar radiation and high temperatures and poor color development due to lasting high temperatures. These outcomes have been reported for grapes, apples, persimmons and unshu mikan oranges.

In the case of peaches, "water-soaked brown flesh" disorder, which is damage to the flesh that cannot be visually identified from the exterior, can occur especially in western Japan, where the temperature can easily become high and where annual rainfall is also much. This damage causes unstable quality as well as other concerns.

Climate change is projected to shift areas suitable for the production of unshu mikan oranges, grapes and other fruits. If global mean temperature compared to the 1990's increases by 2°C, for example, the area in Hokkaido suitable for wine grape production is projected to increase at a lower altitude.


Figure 10. Poor coloring of grapes (variety: Pione) (above left); sunburn damage on apples (variety: Fuji) (above right); poor coloring of apples (below left); "water-soaked brown flesh" disorder in peaches (below right)
Source: Reference 9, 10 and 11

## Southern migration of Pacific saury will be delayed (Projection)

A delay in the southern migration of Pacific saury has been projected in analyses of saury migration volume projection models combined with data on projected sea surface temperatures after global warming.

According to the projection, the peak of stock biomass from migrating Pacific saury will shift to early October to early November for waters off eastern Hokkaido, mid-November to mid-December for Sanriku waters, and mid-December and after for Joban waters.

Another possible impact is a gradual decrease in the body weight of each harvested saury as the migration period shifts.

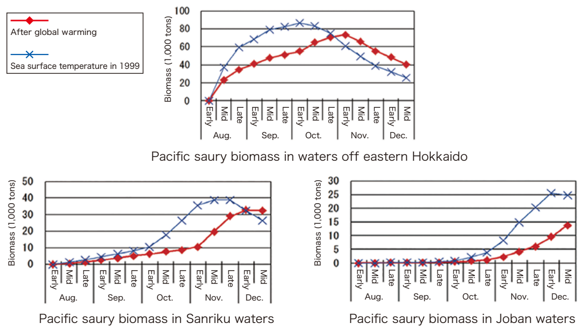


Figure 13. Change in estimated Pacific saury biomass in different waters (Examples based on sea surface temperatures in 1999)
Source: Reference 13 (partially revised)

# Impacts of Climate Change (Natural ecosystems)

The impact of climate change on natural ecosystems has already been observed, including changes in the distribution of vegetation and wildlife. As these cases are projected to advance further, impacts on the variety of benefits humans receive from the ecosystems ("ecosystem services") are also of concern.

## Migration route of Oriental honey-buzzards will change (Projection)

Oriental honey buzzards, which are birds of prey that breed in Japan, in the fall migrate west along the Japanese archipelago, across the Goto Islands and the East China Sea to China.

According to a study on the assessment of future changes in the migration route of Oriental honey-buzzards, the northeast wind (tailwind for Oriental honey-buzzards) will change above the East China Sea in the fall. By the mid-21st century (2046 -2055), a large portion of the autumn sky over the East China Sea may become unsuitable for migration, and eventually the entire sky by the end of the 21st century (2091-2100).

Figure 14. Oriental honey-buzzard in flight

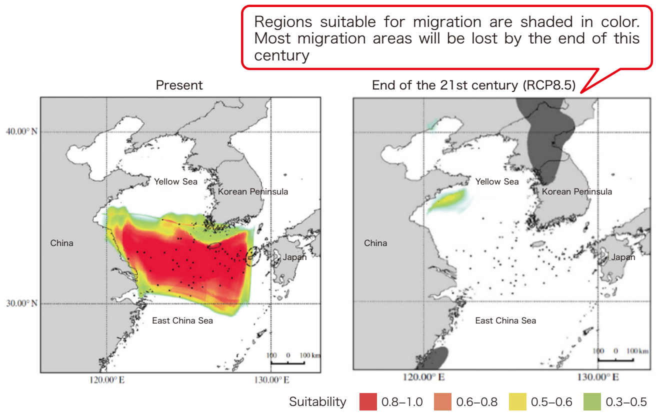


Figure 15. Present and projected autumn migration route of Oriental honey-buzzards
Source: Reference 14 (partially revised)

## Bamboo forests will invade mixed forests (Projection)

Climate change may alter the rural scenery around us.
The problem of abandoned bamboo forests is now a concern mainly in western Japan. When climate change advances, bamboo forests will settle in eastern and northern Japan and possibly cause adverse effects on local ecosystems and biodiversity, as well as rural landscape management.
Potential habitats of bamboo (moso bamboo and madake bamboo) in central and northern Japan are projected to increase from 35% (1980-2000) to 51-54% (2°C above preindustrial condition) and 77-83% (4°C) during future period (2076-2096). The northern limit of bamboo growth is projected to move 500 km northward, reaching Wakkanai, Hokkaido under 4 °C warming level.

Figure 16.
Bamboo forests invading into mixed forests in a rural area (Zushi, Kanagawa)
Source: Reference 15

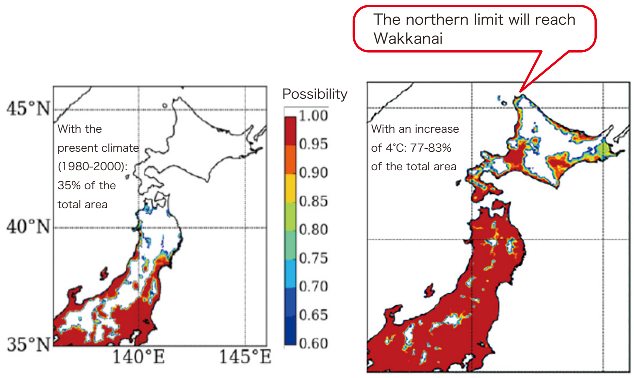


Figure 17. Projected suitable habitats for bamboo forests under the present and the future climate conditions
Source: Reference 15

## Seaweed beds will degrade or disappear (Present/Projection)

With the increase in ocean temperature caused by climate change, spawning and feeding grounds, as well as migration routes, of marine organisms in offshore and coastal areas are likely to change, causing a direct impact on their distribution. In shallow waters, areas for seaweed cultivation and tidal flats may be reduced or species diversity may decline, causing concerns about the impact on industry.
In 2013, large scale losses of cultivating grounds for arame (Eisenia bicyclis) and kajime (Ecklonia cava) seaweed were observed over a length of 200 km along the coast of northern Kyushu and Yamaguchi Prefecture. High temperature ocean is considered to be the cause of this large-scale, rapid loss of seaweed cultivation ground --possibly the first such case.
With projections under the RCP2.6 and RCP8.5 scenarios, areas unsuitable for kajime seaweed growth are likely to expand by the end of the 21st century along Honshu to Kyushu as the ocean temperature rises.

Figure 18. Clump of seaweed washed ashore (2013)
Source: Reference 16

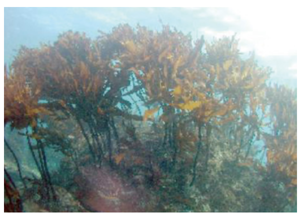

Figure 19. Kajime seaweed community
Source: Reference 17

# Impacts of Climate Change
# (Water environment/ Water resources, Natural disasters/Coastal areas)

As impacts of climate change on the water environment and water resources, a rise in water temperature in public waters due to the increase in atmospheric temperature, as well as damage to water supplies (volume reduction or discontinuation) due to draught, have been reported. As impacts of climate change on natural disasters and the condition of coastal areas, the flooding of rivers due to increased intensity and frequency of sudden downpours, damage due to slope failures, high tides due to more intense typhoons, and other damages have become a concern.

## River flow conditions will change (Projection)

While climate change alters the volume and pattern of rainfall, some areas may receive more rain instead of snow. In Japan, where mountains cover a large portion of the land, such conditional changes are projected to greatly alter river flow conditions (annual feature of water volume in rivers).
Calculations of river flow volume with projected climate conditions in the near future and at the end of the 21st century show a large change in river flow conditions in areas on the coast of the Sea of Japan that receive heavy snowfall.

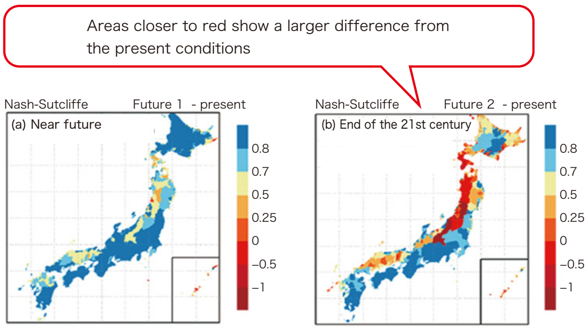


Figure 20. Projected change of river flow conditions caused by climate change in different areas in Japan
Source: Reference 18 (partially revised)

## Multiple water disaster and sediment disaster in watersheds (Projection)

As a trend toward the increased occurrence of downpours has been seen in recent years, there is concern about more serious slope failures and different patterns. Examples include large-scale damage caused by increased occurrence of deep slope failures, development of landside dams caused by blocked rivers, flooding caused when such landside dams break, secondary disasters caused by raised river beds due to deposits of a large volume of sediment, elevated volume of driftwood due to increased occurrence of deep and surface slope failures, and flooding caused by the resultant piles of driftwood.
When torrential rainfall hit northern Kyushu in 2017, slope failure and debris flows over wide areas directly caused damage. At the same time, a massive volume of sediment flowed to downstream areas, nearly covering the rivers. This raised the river bed, causing flooding on a massive scale. When climate change increases the frequency and intensity of rainstorms in the future, it is feared that similar levels of serious damage may occur in other areas throughout the nation.

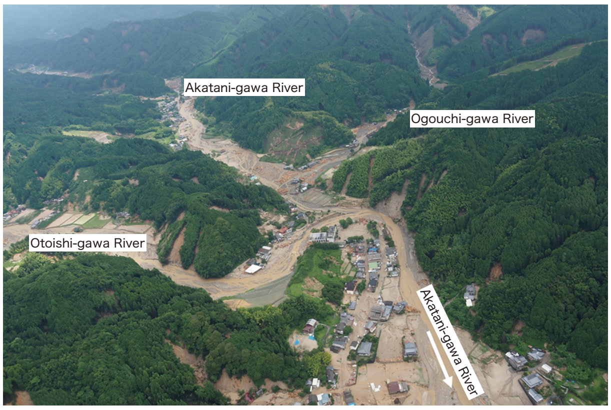


Figure 21. Damage from the torrential rainfall in northern Kyushu in 2017 (damage caused by driftwood at the point where Akatani-gawa River, Ogouchi-gawa River and Otoishi-gawa River merge in Asakura, Fukuoka)
Source: Reference 19

## Storm surge caused by typhoon (Projection)

A storm surge is a phenomenon where the sea surface rises from the usual level due to decrease in atmospheric pressure or wind. Storm surges caused by typhoons are known to occur more prominently at the back of a bay and vary depending on the intensity and track of the typhoon.
Japan experienced serious storm surge damage when typhoons hit the country. Typhoon CHABA (TY0416) in 2004, for example, brought massive damage to the Setouchi Region. In the city of Takamatsu in Kagawa Prefecture in particular, coastal land area became flooded and the ocean flowed back the rivers, causing large-scale flood damage.
Although quantitative projection of future typhoons for specific areas is still not possible, a study that employed a trial projection showed that changes in storm surges will not be felt evenly throughout the country. Specifically, storm surges are projected to increase in eastern Japan, while staying the same or decreasing in western Japan.

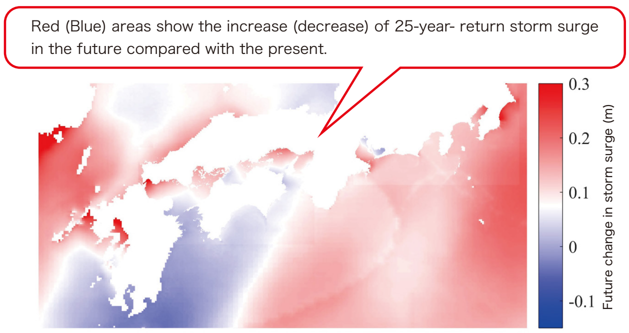


Figure 22. Example of the projection of future changes in the 25-year-return storm surge with uncertainty
25-year-return storm surge: A storm surge that occurs with a probability of once in 25 years. Source: Reference 18

# Impacts of Climate Change
## (Human health, Industrial/Economic activity, Life of citizenry and Urban life)

The impact of climate change on human health includes direct impact due to heat. Regarding industrial and economic activities, as well as lives of citizenry and urban lives, a rise in temperature, the rise of sea surface and extreme climate phenomena will impact a variety of production and sales activities as well as various types of infrastructure.

### Incidence of heat illness will increase (Present/Projection)

Heat illness comes as a direct impact of heat and is considered to be closely related to climate change. The number of fatalities due to heat illness is on an increasing trend, with a record high seen in 2010, when extreme temperatures also broke records*.
Under the RCP8.5 scenario, the projected number of cases where heat illness patients will be carried by an ambulance will increase nationwide in the period between the present (1981-2000) and mid-21st century (2031-2050). In particular, the number is projected to at least double in eastern and northern Japan.

*It must be noted that the classification of fatalities in Japan was revised starting from 1995.

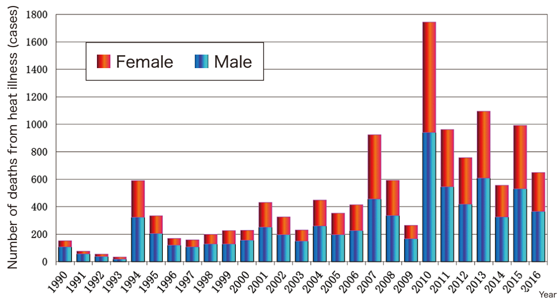


Figure 23. Number of deaths from heat illness by year and gender (1990-2016) Source: Reference 20

### Various impacts will occur regarding industrial and economic activities as well as lives of citizenry (Projection)

To manufacturing, commerce, construction and other industries, increased frequency and intensity of torrential rainfall, strong typhoons and other extreme weather events are likely to bring about massive damages.
To our daily lives, a rise in temperature may disrupt comfortable living conditions or change our sense of seasonality.
In addition to these direct impacts from changing weather patterns, indirect impacts, such as changes in natural ecosystems, impacts on agriculture and fisheries, and effects on natural disasters, can cause a wide variety of secondary effects on industrial and economic activities as well as our daily living conditions.

There is a concern that the impact of climate change in different parts of the world may affect Japan's industry and economy through supply chains.
The flooding of the Chao Phraya River in Thailand in 2011 brought damages to Japanese companies in local areas. Through the supply chain of hard disks, estimated damage to domestic companies was around 315 billion yen. Although it cannot be easily concluded that the flooding was caused by climate change, if climate change increases the frequency and intensity of flooding, similar serious damage is projected to occur around the world.

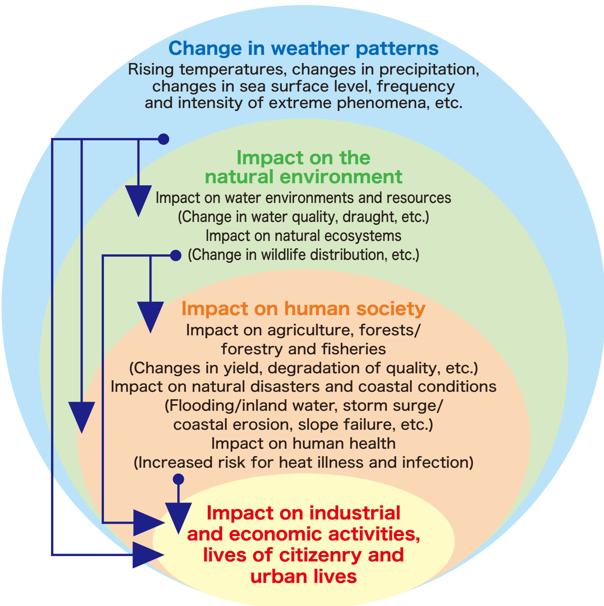


Figure 24.
Flow of the impact of climate change on industrial and economic activities, lives of citizenry and urban lives

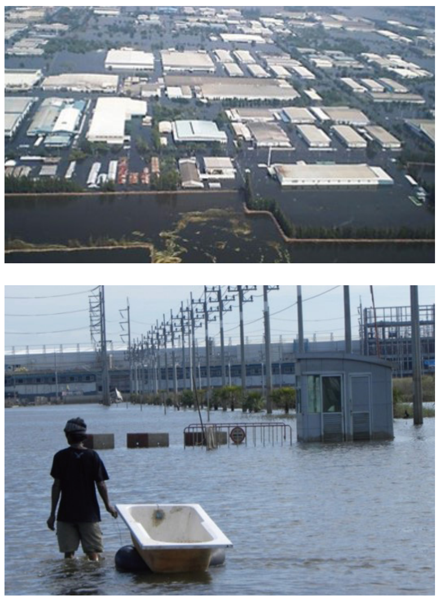

Figure 25. Impact of the flooding of the Chao Phraya River in Thailand
Source: Reference 21

# Adaptation Measures are already engaged in efforts

## “National Plan for Adaptation to the Impacts of Climate Change” decided by Cabinet

As described above, the impact of climate change has already been observed in Japan and various areas and sectors all over the world. When the intensity of climate change becomes strong in the future, the possibility of serious, wide-spread and irreversible impacts will increase. This means measures for “mitigation,” or measures to control the emissions of greenhouse gases, are not enough. We need to take measures for “adaptation,” or measures to deal with the impacts that are already here as well as medium- to long-term impacts that are inevitable.

To take measures against the impact of climate change, in order to promote compatible measures in comprehensive and systematic ways for the entire Government, the Japanese Cabinet adopted the National Plan for Adaptation to the Impacts of Climate Change in November 2015.
The Plan includes basic principles, basic approaches, basic directions for measures in each sector, and basic and international measures. Various types of specific measures are taken now based on the plan.

## Growing crops adapted to global warming

In agriculture, measures to deal with global warming have been taken. For example, some farmers have started growing, or have changed their crops to, subtropical or tropical crops, which can be grown even with a rise in temperature.
In the Nanyo Region of Ehime Prefecture, for example, farmers started growing Tarocco orange, a type of blood orange, which can tolerate the summer heat. The oranges have been grown in larger areas and their yield is increasing, while also being highly praised in the market. On the islands and coastal areas of Matsuyama, Ehime Prefecture, avocado cultivation has already started.

Figure 26. Tarocco orange (left) and avocado (right) cultivation has started in Ehime Prefecture  Source: References 9 and 22

## New businesses focusing on climate change

Business sector begins to take advantage of the opportunity brought by climate change.
Examples include businesses that offer services using information and communication technologies (ICT), such as agriculture support services, services to project and assess risks from disasters, and services to manage the heat stress of outdoor workers. Also, technologies to improve the heat-tolerance environment and the comfort of buildings and houses, as well as weather derivatives, or financial instruments to insure possible damages due to abnormal weather events, have been offered in new business development.

| | |
|---|---|
| Agriculture | - Offer agricultural services through the use of ICT to monitor, deliver and record weather events, and information, etc. that are necessary for agriculture. |
| Natural disasters | - Offer technologies to project and assess possible areas for flooding and the risks of flooding inside buildings.<br>- Offer services to design and construct flood and rainstorm resistant buildings and houses. |
| Human health | - Introduce Japanese-style mosquito nets to prevent mosquito-borne infectious diseases in developing countries. |
| Industrial/ Economic activities | - Offer financial instruments to hedge against the risks of abnormal weather events, such as weather derivatives.<br>- Offer ICT-driven systems to manage the heat stress of outdoor workers. |
| Life of Citizenry and Urban life | - Offer technologies and products to improve the heat-tolerance environment and the comfort of buildings and houses.<br>- Plan residential area development by taking air movement and “cool spots” into consideration. |

Table 1. Example climate change businesses already started
Source: Reference 23

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